Understanding nitrogen's role in the ocean

Editor's Note: Journalist and crew member Kathryn Eident and scientist Jeremy Jacquot are traveling on board the RV Atlantis *on a monthlong voyage to sample and study nitrogen fixation in the eastern tropical Pacific Ocean, among other research projects. This is the fourth blog post detailing this ongoing voyage of discovery for* ScientificAmerican.com

RV *ATLANTIS* MAIN DECK—For years scientists have thought that the amount of nitrogen coming into and out of the world's oceans was relatively equivalent, creating a "balanced" and naturally maintained budget. But this theory has been based on a relatively small amount of data obtained from only a few of the world's oceans, leaving room for scientists to question how accurate the model is.

"It's not clear whether the marine nitrogen budget is balanced or not," geoscientist Angela Knapp said in a recent shipboard science meeting. "Are we underestimating nitrogen fixation? Are we overestimating denitrification?"

This assumption has led Chief Scientist Doug Capone, Knapp, Will Berelson, a geochemist from USC, and the other 25 scientists aboard this cruise to venture to the Eastern Tropical Southern Pacific (ETSP) to answer

the questions: can the ocean maintain a well-regulated nitrogen budget? And if so, how?

Though Capone has contributed extensive research on nitrogen fixation (the transformation of gaseous nitrogen into biomass) in the northern Atlantic Ocean and in the Arabian Sea, scientists know very little about nitrogen use in the southern Pacific Ocean and how it affects the overall budget.

To understand how nitrogen is used, a basic understanding of the marine nitrogen cycle is necessary. In simple terms, there are four processes in the nitrogen cycle. Two of those processes make up the bulk of nitrogen entering and leaving the world's oceans: nitrogen fixation and denitrification.

In the water column, some organisms "fix" or convert nitrogen from gas into a biologically useful form, such as nitrate. But other organisms can take compounds like nitrate and "denitrify" or convert them back into nitrogen gas, essentially putting it back into the atmosphere. These two processes add and remove nitrogen from the oceans, respectively.

Additionally, nitrogen compounds are cycled into the ocean when ammonium (a form of nitrogen) is converted into nitrite and nitrates. These processes are called nitrification and involve the transfer of nitrogen between microbes in the ocean.

In addition to understanding where these processes are happening in the oceans, scientists also need to know how organisms use nitrogen in conjunction with a variety of other nutrients like phosphate, iron and oxygen. One tool they use is the "Redfield Ratio," created by oceanographer Alfred Redfield in the 1930s. This ratio says that in a given biomass of phytoplankton, or in any ratio of nutrients in the deep ocean, scientists should be able to observe a ratio of approximately 106 carbon molecules to 16 nitrogen molecules to 1 phosphate molecule (106:16:1). They can use this as a standard to help them understand other processes in the oceans.

For instance, in areas where this ratio is different—say when the ratio of phosphate to nitrogen is higher—scientists would expect to find more nitrogen fixers. For instance, in the ETSP, there is a higher rate of phosphate

to nitrogen, leading some scientists to believe there is more denitrification going on than nitrogen fixation. But—no one will be sure until they compile enough data.

Knapp is looking for evidence of these processes by studying nitrogen and oxygen isotopes. An isotope is an atom that has a different number of neutrons than another atom of the same element.

For example, 14nitrogen has fewer neutrons than 15nitrogen, making 15nitrogen heavier. Organisms that denitrify nitrogen compounds may prefer one type of nitrogen isotope to another, so by studying different isotopes, scientists can get a molecular look at this complicated process.

Scientists are also looking at how iron's presence or absence in the ETSP may affect the nitrogen cycle. Iron is an essential nutrient for all photosynthesizing organisms, and it's especially important for those who fix nitrogen, as well. If scientists find that these waters are iron deficient, they may be closer to concluding that nitrogen fixation is limited in this area.

While the hundreds—perhaps thousands—of samples and data sets scientists gather on this trip will contribute information to a growing database, it may take years for them to develop a more accurate picture of the marine nitrogen budget.

"Over the past five years, people have started to think that maybe nitrogen fixation is happening in the eastern Pacific," Knapp said. "But it's all indirect assumptions, so that's why we're here."